



Physico-chemical Characterization of Solutions from Cooked Beans and Their Comparison with Human Urine: Fertilizer and Food?

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Authors' contributions

This work was carried out in collaboration among all authors. Author JCFT designed the study, performed the statistical analysis, managed the literature searches, wrote the protocol and wrote the first draft of the manuscript. Authors INT and PDD managed the analyses of the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/EJNFS/2020/v12i1230331

Editor(s):

(1) Dr. Hudson Nyambaka, Kenyatta University, Kenya.

Reviewers:

(1) Ibrahim Iro Ibrahim, Federal College of Forestry Resource, Nigeria.

(2) Pankaj Kumar Ray, Bihar Agricultural University, India.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/63712>

Original Research Article

Received 15 October 2020
Accepted 21 December 2020
Published 31 December 2020

ABSTRACT

The present paper aims to highlight the chemical characteristics of solutions from cooked beans and to compare them with human urine. Solutions of cooked beans were produced by cooking variety of *Phaseolus vulgaris* L. known as "Meringue" without salts. After this stage, samples of those solutions and samples of the water used for the cooking process were collected for laboratory analysis. A solution from cooked beans is rich in mineral salts, particularly major macro elements (N and K) and minor macro elements (Ca, S, Mg). Concerning the third major macro element, notably the phosphorous, it is present in low amounts. The advantage of this fluid consists in its low amounts of sodium and chlorides, coupled to its low electric conductivity. This fluid has a pH of 6.31. It is made of about 90% of water. A deep parallelism can be established between the human urine and solutions from cooked beans. In fact, these two fluids are rich in nitrogen and potassium, and mainly made of water. But, in the detail, some particularities are present. Human urine has high amounts of sodium and chlorides, this coupled with a high electric conductivity. Concerning solutions from cooked beans, it has high amounts of calcium and magnesium, and a

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quite nil electric conductivity. The solutions from cooked beans do not require a dilution, but a rinsing directly after its application in order to avoid the loss of sulfur and nitrogen through gas emanation. Moreover, the numerous nutrients contained in solutions from cooked beans can be gainfully recycled as soup after flavoring.

Keywords: Used water; sanitation; recycling; fertilization; agriculture; nutrition.

1. INTRODUCTION

In ACP (Africa, Caribbean, and Pacific) countries, the demographic explosion [1], the reduction of tillable lands, and the reducing of the fallow periods [2] represent today the most perceptible phenomenon. This part of the world is peopled essentially by resource-poor farmers, with soils as their principal source of earnings [3]. Hence, to insure their survival, they cultivate even the most sloping plots [4]. Various and risky farming techniques are noticeable here [4], the aim being the desire of the daily satisfaction of their needs in food. In consequence, the yields decrease year after year [5,3], attesting then the permanent depletion of soils fertility. If a minority among these peoples can easily acquire synthetic fertilizers to solve short term problem of soils fertility depletion [6,7,8], the majority can't. But, even in the first group of these populations, the solution for soil fertility is not completely acquired because of the remaining of queries. In fact, a fraction of them up to today lacks of knowledge about the use of these chemicals, since they could be pollutants when poorly used [9]. Moreover, those chemicals are sometimes rare, and their solubility is not often guaranteed [10]. Concerning the second group of these peoples, represented by resource-poor farmers, possess synthetic fertilizers is simply a fairytale. Their survival then appears today with acuteness. That's why day after day, researchers investigate different sectors since the beginning of the twentieth century in order to provide fertilizers at low costs, easily used, efficient, and available for the poorest people worldwide. The tendencies of the results obtained today are encouraging. So, in some parts of the world, many were taught in how to use rocks [11,12], plants such as *Titonia diversifolia* [13], and mixtures of organic fluids [14,15] among all as fertilizers. These approaches already constitute exits for that problem despite their local character; in fact, geological and floral diversity all over the world generates variations in their application. In front of these signs of potential victories, scientists have not given up; in that way, [14] recently showed that the mixture of human urine and solutions from cooked beans

can pertinently enhance the growth of plants. To comfort the contribution of the solutions from cooked beans as potentials nutrients provider, [16] successfully tested them as substrate for some heterotrophic organisms, notably moulds. He justified the choice of moulds by their inability to manufacture by themselves their food, and then, condemned to be often looking for external incoming of organic matters, mineral salts and water, both necessary for them to realize their vital functions as proved by [17]. Despite these favorable results, gaps remain about the knowledge related to solutions from cooked beans: their physico-chemical characteristics. Make the light on that aspect will finally present those liquids as same as many other fluids from kitchens as source of nutrients for plants according to the actual concept of sustainable development. The present study aims to comfort the observations made by [14,15,16] concerning the potential agri-use of the solutions from cooked beans. In the detail, this is about demonstrating the fact that solutions from cooked beans are a complete organic fertilizer. In that point of view, its content in major elements both required for an optimal plants and soils nutrition will be highlighted here.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Beans seeds

Most of the Africa inhabitants practice agriculture [18,19,20], with beans as one of the main crops [21]. That plant is appreciated all over Cameroon because of its dietetically potential [22,23,24]. In that way, 100 g of that food is made of 9.06 g of proteins, 27.91 g of carbohydrates, 0.49 g of fats, 5.3 g of fibers, 61.2 g of water, 0.257 mg of B1 vitamin (thiamine), 0.063 mg of B2 vitamin (riboflavin), 0.57 mg of B3 vitamin (niacin), 0.299 mg of B5 vitamin (pantothenic acid), 0.175 mg of B6 vitamin, 0.98 mg of E vitamin (tocopherole), 3.7 µg of K vitamin, 168 µg of total folate, 1337 mg of potassium, 225 mg of sulphur, 414 mg of phosphorus, 140 mg of magnesium, 113mg of calcium, 47 mg of chloride, 6.5 mg of iron, 2.5 mg of zinc, 2.3 mg of iron, 3.5 mg of sodium,

0.96 mg of zinc, 0.635 mg of copper, 0.548 mg of manganese, 0.430 mg of boron, 0.271 mg of copper, 0.183 mg of nickel, 0.02 mg of chrome, 0.095 mg of fluoride, 0.0052 mg of cobalt, 0.0018 mg of iodate, and 0.0014 mg of selenium among others [25,26,27,28]. The amount of the total nitrogen can be deducted from the rate of the proteins with the help of the Jones factor [29]; in fact, the amount of the proteins = total nitrogen*6.25 (with 6.25 as the Jones factor). For the present case, we have 1.4496 g of total nitrogen in bean seeds.

About 85% of their product is directly eaten in some of the countries where it is produced. The remaining 15% is sold [30]. Particularly in Cameroon, large quantities are produced every year, and are mainly intended for export [31]. Bean seeds represent an important source of vegetal proteins, their flatulent effect is universally known and has, undoubtedly, been a source of discomfort throughout history [32]. Integument of bean seeds is permeable or semi permeable, allowing then diffusion phenomenon to occur through it [33].

2.1.2 Solutions from cooked beans

Solutions from cooked beans are heterogeneous mixtures, and particularly a proteic globular suspension, with considerable amounts of carbohydrates. It has a pH value of 6.4. At rest, that water divides itself into two superimposed domains: a flaky superficial domain and a liquid lower domain. The flaky domain is the organic part and the liquid domain is the water and the mineral salts provider. The density of the flaky domain is 0.964 and that of the liquid domain is 1.011. The average speed of the growth of *Aspergillus L.* at the surface of the solutions from cooked beans is 3,17 cm²/H; they cover in five days a surface of 379.74 cm². The physico-chemical characteristics of the flaky domain floating on the liquid domain make it an adequate area for the development of moulds (*Aspergillus L.*). Solutions from cooked beans Seems to contain all the nutrients required for an optimal development of moulds (*Aspergillus L.*), and in the same way for an optimal fertilization of soils; this include water, organic matters and mineral salts among which nitrogen, potassium, phosphorus, sulfur and calcium can be named. It is then a complete liquid organic fertilizer. Those solutions position themselves also as a high grade activator for soils micro flora. It represents finally a way for a sustainable improvement of agriculture in developing countries and a way for

a sustainable development of soils micro flora, required for achieve the food self-sufficiency [16].

In daily life, many pig farmers feed their animals with spent grain mixed with solutions from the end of cooking the beans; results are wonderful. Moreover, those solutions are used in the confection of some meals in Cameroon known as "pilé" in many tribes. This action is justified by the increasing of the nourishing potential of the food. In addition, when solutions from beans cooking are spread out, after ten of minutes, one can easily feel the emanation of a loud smell; that odor disappears within two or three day according to the quantity of solutions thrown [33].

2.1.3 Human urine

An adult produces daily about 1,500ml of urine in average, and a child about the half. The quantities excreted are principally under the control of the amount of the water drunk, the transpiration rate, the daily activities, and the climate. Depending on the person's state of health, his urine may or may not be sterile [34]. If the urine of a healthy individual is amber-yellow in color, however, it becomes clearer depending on his hydration and state of health [35]. The smell of the urine varies, depending on the diet [36,37]. But, if the characteristic smell of ammonia appears as soon as the urine is released, it is one of the signs of a urinary tract infection [38]. At the moment of the release, the pH of the urine varies between 6.32 and 8; when stored, that parameter can reach about 9 [33]. Its electric conductivity varies from 14.8 to 25.4 mS/cm. Its concentration in total organic carbon is 3.62 to 6.674 g/l [39]. Urine has over the ages found many functions in the human community: medicines and detergent [40], source of energy [41,42], additive substance for painting (Oxidation paintings or Piss paintings) [43], architectural representation [44], fertilizer [45,46,47,48,49,50,51]. Urine has a high nutrients availability compared to synthetic fertilizers. Its agri-use has been declared non harmful for the environment [52,53]. This agri-use is justified by its composition: urea (CO(NH₂)₂ [54,55], creatinine (C₄H₇N₃O [56,57], uric acid (C₅H₄N₄O₃), hippuric acid (C₉H₉NO₃), urobilirubin (C₃₃H₄₂N₄O₆), kidney toxins, medicines, doping substances, potassium (from 590 to 3,300 mg/l), chloride (from 2240 to 3030 mg/l), sulphates (from 175 to 225 mg/l), sodium (from 938 to 982 mg/l), phosphates (from 200 to 1,800 mg/l), carbonates (200 mg/l), ammonium (from 1120 to 8570 mg/l), calcium (from 13.34 to

15.75 mg/l), magnesium (from 1.5 to 1.63 mg/l) [58,59,60,61,62,63,64,65,66].

2.1.4 Area of the studies

The well for domestic use that provided the cooking water is located in the locality of Yaoundé, at mid-slope of an interfluvial, at about 5.5m from latrines, and at open air. The climate of the locality is of Guinean equatorial type, with four different seasons [67]. The average annual rainfall in Yaoundé is 1,600 mm, for an average temperature of 23°C. [68]. The geological substratum is made of embrechites with quartz, garnet, biotite, feldspar, pyroxenes, plagioclase, and hornblende as main minerals. Soils are of lateritic type [69]. On the hydro geological point of view, the crystalline substratum of the Yaoundé region is essentially constituted by two superimposed aquifers: an upper aquifer (within alterites), located between 5 and 20 m depth, and a lower aquifer (in substratum discontinuities), located at depths greater than 20 m [70].

2.2 Methods

Field and laboratory studies help to reach the targets.

2.2.1 Field work

Field work helped to acquire bean seeds, necessary for the production of solutions of its end of cooking process. The type bought is commonly known as “Meringue” (photo 1), one of the representative of *Phaseolus vulgaris* L. *Species*.



Photograph 1. « Meringue »

2.2.2 Laboratory tests

2.2.2.1 Manipulation of bean seeds samples and production of solutions from their end of cooking process

In the laboratory, beans samples were sorted out in order to remove undesirable particles, and weighted. For the production of the samples of solutions from cooked beans, 2kg of seeds were quickly washed to remove dust and other impurities. Beans were cooked into water without salt to avoid any out coming electrolytes. The resulting suspension (so called solutions from cooked beans) were collected, cooled, and stored in the fridge for future lab tests.

2.2.2.2 Laboratory analysis

Physic-chemical analysis dealt with the identification of Ca^{2+} , Mg^{2+} , K^+ , Na^+ , PO_4^{3-} , SO_4^{2-} , NH_4^+ , Cl^- , and CO_3^{2-} since they are present in bean seeds. Moreover, their choice is motivated by the fact that they can be organized as major macro elements (N, P, K), minor macro elements (S, Ca, Mg, Na), and oligo elements (Fe, Se, Mn, Zn, Cu) for plant nutrition [71]. The process started by the chemical characterization of the water used for the cooking process during which the quantities of the same ions were measured. The lab tests ended with the evaluation of the amount of water in the solutions from cooked beans.

The IonPac CS12A and IonPac AS12A analytical columns were respectively used for the separation of ammonium (NH_4^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), and potassium (K^+) as far as cations were concerned, and chloride (Cl^-) and sulfate (SO_4^{2-}) in the case of anions. The flow rate was set to 1.0 mL/min for both cations and anions optimization. The different cations were isocratically separated with a 20 mM Methanesulfonic acid solution within 15 minutes. Concerning the ions studied here, isocratic elution with 4mM and 20mM Sodium hydroxide solution were employed for their separation, respectively for chloride and sulfate, during 15 minutes. All eluents were degassed and pressurized under high purity nitrogen to prevent dissolution of carbon dioxide and subsequent production of carbonate.

Concerning bicarbonate ion (HCO_3^{2-}), its amount was measured by using titrimetric method. The pH was determined with a pH-meter having a glass electrode. Electric conductivity for its own was measured using a conductivity meter fitted

with a calibrated measuring cell; the results were expressed in mS/cm.

To determine the amount of water, heating was used. In fact, a given quantity of the solution was collected and weighted (M1). After the weighting, it was poured in a metallic container with known mass (M2). After the complete evaporation, the container and the residues were weighted (M3). The proportion of water was obtained through the following calculations: $(M3-M2)*100/M1$. The percentages of the macro elements were obtained as follow: $\%N = \frac{NH_4^+ * 100}{(NH_4^+ + HPO_4^{2-} + K^+)}$, $\%K = \frac{K^+ * 100}{(NH_4^+ + HPO_4^{2-} + K^+)}$, $\%P = \frac{HPO_4^{2-} * 100}{(NH_4^+ + HPO_4^{2-} + K^+)}$, $\%Ca = \frac{Ca^{2+} * 100}{(Ca^{2+} + Mg^{2+} + SO_4^{2-})}$, $\%Mg = \frac{Mg^{2+} * 100}{(Ca^{2+} + Mg^{2+} + SO_4^{2-})}$, $\%S = \frac{SO_4^{2-} * 100}{(Ca^{2+} + Mg^{2+} + SO_4^{2-})}$.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Water for beans cooking

The water for beans cooking has an electric conductivity of 0.029mS/cm and a pH of 5.1.

This water is composed, in decreasing weight order, of 0.0154 g/l of sodium, 0.0095 g/l of potassium, 0.009 g/l of ammonium, 0.0045 g/l of calcium, and 0.0034 g/l of magnesium. Concerning anions, it has, in decreasing weight order, 0.0085 g/l of sulfate, 0.0016 g/l of

chlorides, 0.00146 g/l of phosphate, and 0.0013 g/l of carbonate. Finally, the water used for the beans cooking process is chemically under the control of sodium as major cation and sulfate as major anion (Table 1).

3.1.2 Solutions from cooked beans

The solutions from cooked beans are made of about 90% of water. Its electric conductivity is 0.668 mS/cm. Compared to the water used for the cooking process, a sensible increasing is noticed, about 0.639mS/cm (Fig. 1 and Table 1).

Its pH is 6.31. Compared to the water used for the cooking process, a sensible increase of the present parameter is detected too, of about 1.21 (Fig. 2 and Table 1).

The ionic composition of the solutions from cooked beans reveals the presence of:

- **Ammonium (NH₄⁺):** Its amount is 5.41g/l. Compared to the water used for the cooking process, a high increasing (5.401g/l) of the amount of that ion is noticed (Fig. 3 and Table 1);
- **Potassium (K⁺):** Its concentration is 2.63 g/l. Compared to the water used for the cooking process, a high increasing (2.6205 g/l) of the amount of this ion is detected (Fig. 3 and Table 1);

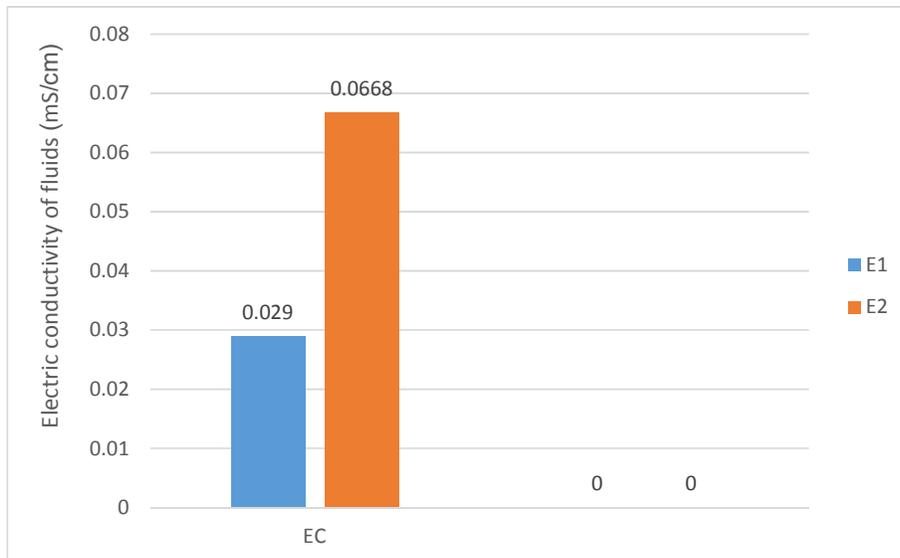


Fig. 1. Evolution of the electric conductivity from the water used for the beans cooking process (E1) to solutions from beans cooking (E2)

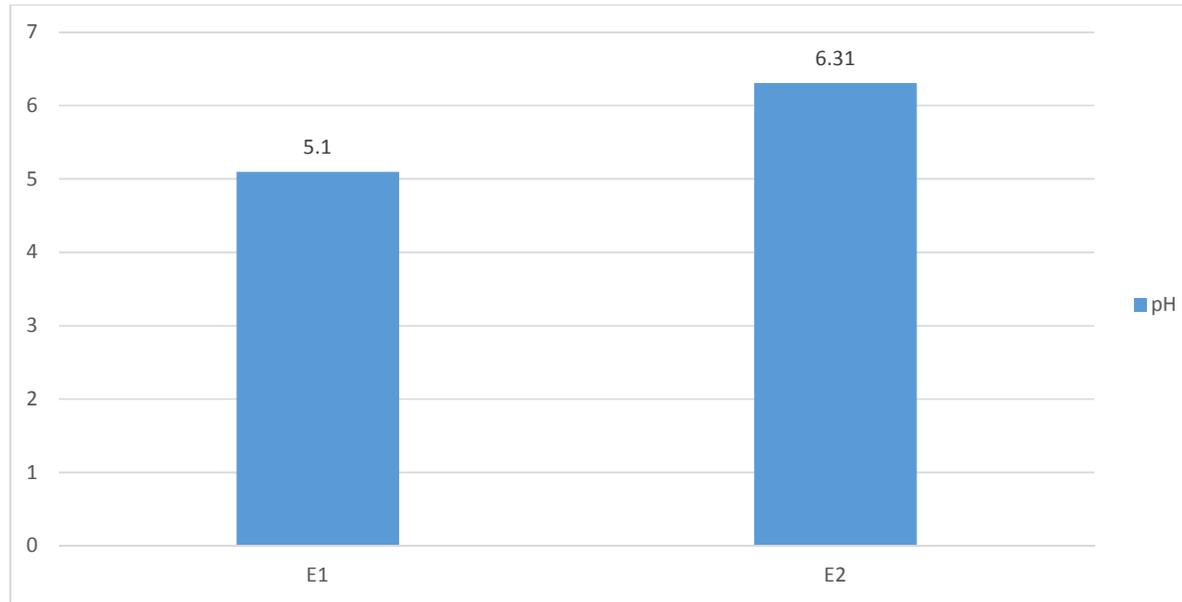


Fig. 2. Evolution of the pH from the water used for the beans cooking process (E1) to the solutions from beans cooking (E2)

Table 1. Physico-chemical characteristics of solutions from cooked beans and the water used for the cooking process

	pH	Ca ²⁺ (g/l)	Mg ²⁺ (g/l)	K ⁺ (g/l)	Na ⁺ (g/l)	CO ₃ ²⁻ (g/l)	SO ₄ ²⁻ (g/l)	HPO ₄ ²⁻ (g/l)	NH ₄ ⁺ (g/l)	Cl ⁻ (g/l)	E.C. (mS/cm)
Water used for the cooking process (E1)	5.1	0.0045	0.0034	0.0095	0.0154	0.0013	0.0085	0.00146	0.009	0.0016	0.0290
Solutions from cooked beans (E2)	6.31	0.403	0.538	2.63	0.07487	0.095	0.29	0.0333	5.41	0.029	0.668

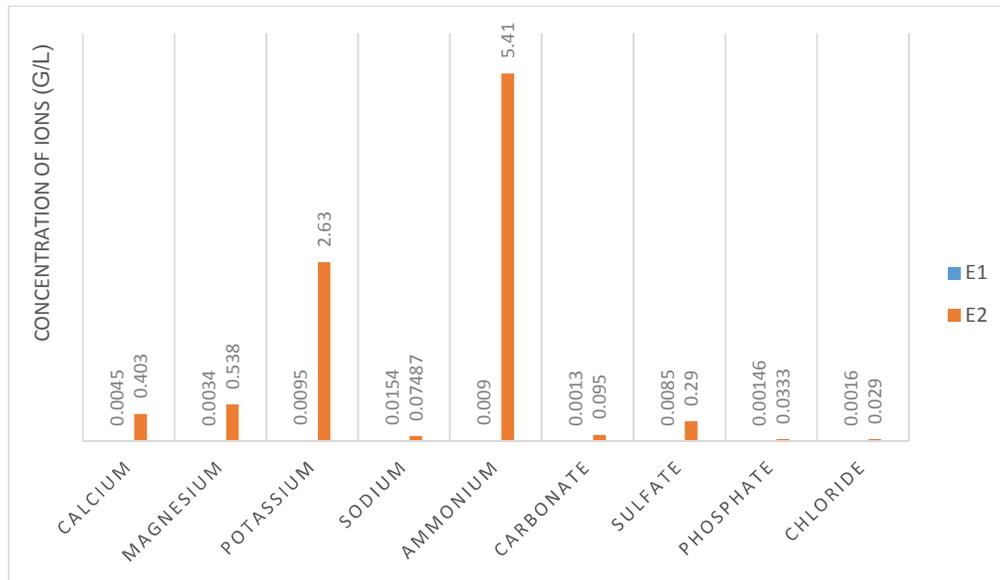


Fig. 3. Evolution of ions from the water used for the beans cooking process (E1) to solutions from beans cooking (E2)

- Phosphate (PO_4^{3-})**: Its concentration is about 0.0333 g/l. Compared to the water used for the cooking process, a high increasing (0.03184 g/l) of the amount of this ion is however detected (Fig. 3 and Table 1). This reveals, despite the low concentration, that the original amount is multiplied 23 times in the solutions from cooked beans;
 - ions is detected (Fig. 3 and Table 1), even if that amount remains low;
- Chlorides (Cl^-)**: Its amount is 0.029g/l. Compared to the water used for the cooking process, a significant increasing (0.0274g/l) of the quantity of the present ions is detected (Fig. 3 and Table 1), even if that amount remains low.
- Magnesium (Mg^{2+})**: Its amount is 0.538 g/l. Compared to the water used for the cooking process, a high increasing (0.5346 g/l) of the quantity of the present ions is detected (Fig. 3 and Table 1);
- Calcium (Ca^{2+})**: Its amount is 0.403g/l. Compared to the water used for the cooking process, a high increasing (0.3985 g/l) of the quantity of the present ions is highlighted (Fig. 3 and Table 1);
- Sulfate (SO_4^{2-})**: Its amount is 0.29g/l. Compared to the water used for the cooking process, a high increasing (0.2815 g/l) of the quantity of the present ions is detected (Fig. 3 and Table 1);
- Sodium (Na^+)**: Its amount is 0.07487g/l. Compared to the water used for the cooking process, a significant increasing (0.05947g/l) of the quantity of the present
 - In short, chemically, all the parameters targeted in the context of this study increase sharply when comparing the water used for cooking the bean and the end-of-cooking solution for the bean (Figs. 1, 2,3 and Table 1). In the detail, if the water used for the cooking process of beans is shyly under the control of sodium and sulfate, solutions from cooked beans is largely dominated by ammonium, potassium, and magnesium. Further on, then come respectively the phosphate, calcium, sulfate, chlorides, and below, sodium. On a completely different level, Fig. 4 reveals a positive correlation between the pH and the electrical conductivity of the solutions studied.

3.2 Discussion

3.2.1 Water used for the beans cooking

The amount of sodium is greater in the water used for the cooking process of beans compared to the amount of potassium. This can be due to

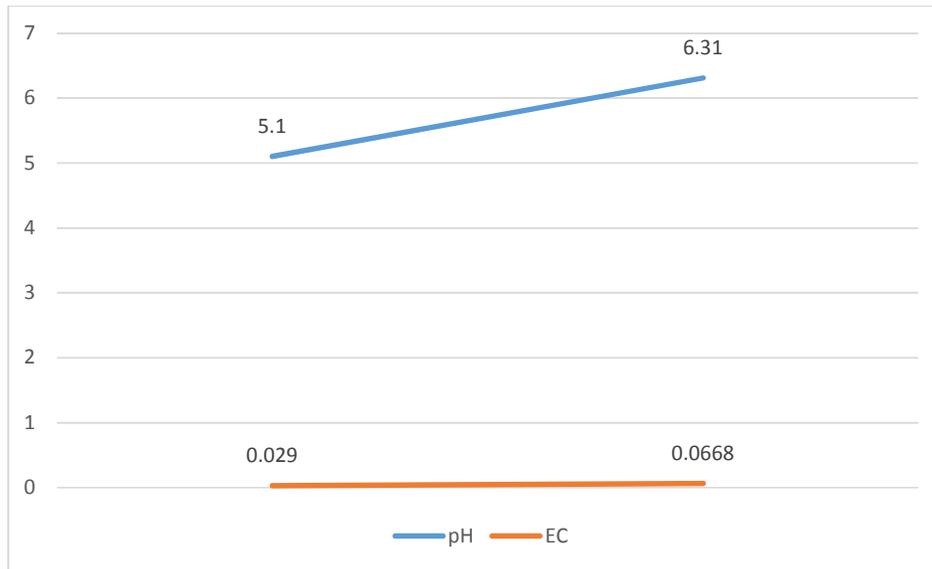


Fig. 4. Correlation between pH and electric conductivity (E.C.) of fluids

the greater stability of K-feldspar and K-micas in one hand, in other hand by the absorption of K in minerals newly formed during the process of alteration as showed by [72], and further on by the atomic mass of K, greater than that of Na, making then the motion of Na easier than that of K. Those two chemical elements are suspected to be from rocks alteration [73]. This is in accordance with the mineral composition (Feldspars, Plagioclases, Hornblende, and Ferromagnesian and the main minerals) of the geological substratum of Yaoundé. Calcium for its own could have been released after the weathering of Feldspar, Plagioclases, Garnet, and Hornblende contained in the substratum (Schist, Gneiss, and Granite) of Yaoundé. The presence of calcium can also be associated to the process of the impoverishment of soils as the consequence of lixiviation process according to [74]. Concerning magnesium ions, they are thought to be from the alteration of ferromagnesian minerals of the substratum. Nitrates are the major forms trough which nitrogen is present in water. That ion can be used as an indicator to testify the pollution of water according to [75]. But when oxygen lacks in an aquatic area, nitrogen manly appears as Ammonium. This corroborates the observations made by [76]. The presence of chlorides can be a direct consequence of the nature of some of the minerals from the Yaoundé substratum. In fact, [77,78] demonstrated that their presence is one of the prime characteristics of groundwater

in basement region; it is then in accordance with the presence of Hornblende and Biotite, which are among the chloride bearers. Moreover, [79] demonstrated the possible substitution of Cl-OH type, responsible of the liberation of chloride in water. Further, the presence of chlorides in this water can be justified by atmospheric inputs following infiltration of rainwater [80], and by the alteration of silicate minerals [81]. Bicarbonates are present in the water used for the cooking process. This can be due to the dissolution of atmospheric and pedological carbon dioxide [82]. It can be also due to the anthropic factors as showed by [83,84]; this is in accordance with the presence of latrines around the well from which the water used for the cooking process of the beans was collected. Regarding the presence of sulfates, it can be due to the alteration of sulfur bearing minerals from the substratum. This corroborates the presence of Pyrite in the gneissic rocks from the Yaoundé region as revealed by [79]. However, meteoric inputs [85] as same as anthropogenic pollution [81] could be considered as far as the presence of sulfates in the water used for the cooking process of beans is of concerned. The pH of the present water is 5.1; after [86], it is acid. The electric conductivity of the same water is 0.029mS/cm. Such a value certifies a low mineralization of the concerned water since it remains very low compared to the standard established by [87]. According to the abacus proposed by [86], the present water in nonconductive.

Finally, the results of analyzes of the water used for cooking the beans in the context of this study are consistent with the data obtained by [88].

3.2.2 Solutions from cooked beans

Significant enrichment in the different chemical elements followed up in the present study is noticed in solutions from cooked beans. This can be explained by the leaching of those elements by beans seeds in contact with water during the cooking process. In fact, when the seeds come into contact with water during cooking, they absorb water and swell. Such phenomenon was previously described in the different stages of the germination of seeds by [89]. This observations corroborates the conclusions of [90] and [33], who consider biological membranes as permeable or semi-permeable, and then suggested to diffusion phenomenon, responsible here to the enrichment of the solutions from cooked beans in mineral salts and in protein derivatives as stated by [16]. This can then be used to explain the fact that in Cameroon, many pigs breeders often mix up the food of their animals with that fluids or simply give it to them as drink; on the field, the results of such practice are wonderful as highlight by [33]. In the same vein, according to [33,91], and [89], this enrichment is facilitated by the temperature, materialized here by the boiling which leads to the cooked stage of the seeds. If such observations reveal the fertilizing characteristics of the solutions from cooked beans as showed by [33,14], and [16], it also induces a real dietary concern with regard to the consumption of beans. In fact, solutions from cooked beans, considered as waste water in Cameroon by many populations, are most of the time throw away at the end of the cooking process. Even if some of housewives are beginning to understand the nutritional importance of this end-of-cooking fluid, much remains to be done to reconcile these latter and this fluid which undoubtedly has an important nutritional value as shown by the sudden improvement in the contents of exchangeable basic cations, nitrogen, phosphorus, sulfur, among others. Many other facts contribute to certify the richness of the solutions from beans cooking. In fact, when those solutions are abandoned at open air, few hours after, emanations of heavy smells can be felt. This could be surely due to the simultaneous releasing of sulphurous and ammoniacal gases, which take separately, are often characterized by very strong odors according to [33]. Likewise, in the particular case of sulphurous gases,

volcanologists like [92] characterize the smell of sulfur dioxide by speaking of the smell of rotten eggs; this therefore justifies the ability of the bean to provoke the phenomenon of flatulence in consumers as described by [32]. Similarly, just a few days after giving up this liquid, a thick whitish film develops on its surface that gradually takes on the appearance of a crepe [16]. Characterized that film as heterotrophic beings, belonging to the family of *Aspergillus L.* They are in fact beings unable to manufacture by themselves their foods, consequently requiring an external contribution of organic matter to nourish themselves as showed by [93]. In that way, [94] declared that their feeding needs are: water, mineral salts, and organic matters. These observations are in accordance with the enrichment of soils treated with solutions from cooked beans in exchangeable basic cations and anions; they are also in agreement with the flocculate that is observed in the lower part of this fluid left to stand in a bottle or in any other container as showed by [33]. That flocculate was characterized as organic matter by [16]. This flocculation takes place under the combined effect of Archimedes' weight and thrust, two phenomena closely controlled by the density of the particles in suspension as has been demonstrated by [95]. We can then think here that the spheres concentrated in the lower phase of the end of cooking solutions of the bean stored in the bottles would be the result of the coagulation [96] of organic substances, in particular protein and carbohydrate according to [16], having diffused from the bean seed cotyledons to end up in water due to the high temperature [89]. This is in agreement with the high content of nitrogen and sulfur in this liquid, among the basic constituents of the protein chains in which beans are abundant according to [27].

In order of enrichment, we have nitrogen (5.41g / l), potassium (2.63 g / l) and magnesium (0.538 g / l). These are respectively two of the major macro elements, that is to say entering mainly in plant nutrition, and one of the minor macro elements [71]. According to the work of [27], potassium and phosphorus are among the most concentrated chemical elements in beans. Thus, these authors show that for 100 g of beans, we have 1337 mg (1.337 g) of potassium and 414mg (0.414 g) of phosphorus. By applying the Jones factor according to which proteins = 6.25 * total nitrogen [29], it comes that in 100g of beans, we have 1449.6mg (1.4496g) of nitrogen, which is therefore the most concentrated chemical

element in these seeds. The abundance of nitrogen and potassium in the bean end-cooking solutions is therefore consistent with their concentration in the seeds; their degree of abundance in the bean end-cooking solutions is in the same order as in the seeds; the third major macro element, however, is weakly expressed. This is in agreement with the observations of [33]. Beside the major macro elements, minor macro elements are also well expressed. In fact, calcium and sulfur represent the most concentrated chemical elements after the previous in solutions from cooked beans. Concerning oligo elements, their amounts in the solutions from cooked beans increase too.

The electrical conductivity remains below 1mS / cm. According to [86], the bean end cooking solution is a non-saline fluid. However, the electrical conductivity goes from 0.029 to 0.668mS / cm from the water used for cooking the bean to solutions at the end of cooking. Even if this parameter is very low according to [86], it is however multiplied by approximately 23 in solutions at the end of cooking of the bean. This therefore attests to a mineralization of the bean end-of-cooking solutions, which concretely results in a sudden increase in the contents of the various elements targeted in the context of the present study when switching from the water used for cooking the bean to the end-of-cooking solutions of this food. At the same time, there is a significant increase in the pH value, which goes from 5.1 in the water used for cooking the beans to 6.31 in the bean end solutions, an increase of 1.21 units. This is in agreement with the mineralization of the bean end cooking solutions, certified by the increase in the content of the different elements and the increase in electrical conductivity. Such an observation refers us to the remark made by [87] within the framework of their investigation on the mineralization of underground water in the locality of Yaoundé. The pH value (6.31) obtained in the case of the present study is closer to that previously obtained by [16].

To help characterize drinking water, [88] defined the following thresholds: less than 0.15 g / l for sodium, 0.25 g / l for sulfates, 0.25 g / l for calcium, 0.012 g / l for potassium, 0.05 g / l for magnesium, 0.05 g / l for nitrates, 0.25 g / l for chlorides, and 0.25 g / l for carbonates. Taken individually the chemical elements contained in

the end of cooking solutions of the bean in relation to these standards, it returns that in the end of cooking solutions of the bean, the contents of the main major macro elements (nitrogen, potassium, calcium, magnesium, sulfates) are well beyond the prefixed thresholds. Further on, the phosphate ion contents, according to the observations of [97], reached thresholds above which the phenomenon of eutrophication is noted in the environment. It is then a highly nutritious solution for plants. This is another argument that attests to the high chemical content of the bean end-of-cooking solutions. Such observations definitely reinforce the statements made by [14,15,16,33] according to which they have placed solutions from the end of cooking beans with human urine as the major liquid organic fertilizers.

3.2.3 Comparison between human urine and solutions from cooked beans

In case of the present comparison, only the upper bounds of the intervals were taken into account for human urine (Table 2). Also, only the parameters of urine directly after excretion were considered.

As in urine [39], nitrogen is predominantly expressed in the form of ammonium ion in the bean end-of-cooking solutions. One can explain such a fact by relying on the theory of loss of oxygen by water when its temperature increases as showed by [98].

In human urine, the ammonium content varies between 1.12 and 8.57g / l [39]. In the bean end-of-cooking solutions, it is 5.41g / l (Table 2). Nitrogen represents 71.6% of all major macro elements [71] in human urine while it represents 66.6% of the same elements for the bean end-of-cooking solution. As shown in Fig. 5, nitrogen (ammonium) may be more concentrated in human urine than in the bean end-cooking solutions. Indeed, according to [64], the composition of urine varies according to several parameters. This is the case with the degree of hydration, the climate, etc. However, the ratio between the ammonium content in the urine and the content of the same element in the bean end-cooking solutions is 1.58 (Table 2). This shows that the concentration of this element in these two fluids is comparable.

Table 2. Comparison between the human urine and water from cooked beans

	Human urine*	Solutions from cooked beans	Percentage of macro elements		Human urine parameter/ Solutions from cooked beans parameter
			Human urine	Solutions from cooked beans	
NH ₄ ⁺ (g/l)	From 1.12 to 8.57	5.41	71.6	66.6	1.58
HPO ₄ ²⁻ (g/l)	From 0.05022 to 0.0527	0.0333	0.4	0.4	1.18
K ⁺ (g/l)	From 0.5 to 3.3	2.63	28	33	1.25
SO ₄ ²⁻ (g/l)	From 0.175 to 0.225	0.29	92.93	23.56	0.78
Ca ²⁺ (g/l)	From 0.01334 to 0.01575	0.403	6.5	32.73	0.04
Mg ²⁺ (g/l)	From 0.0015 to 0.00163	0.538	0.67	43.70	0.003
Na ⁺ (g/l)	From 0.938 to 0.982	0.07484			13.12
Cl ⁻ (g/l)	From 2.24 to 3.03	0.029			104.48
pH	From 6.32 to 6.9 after excretion and 9 after storage	6.31			1.09
E.C. (mS/cm)	From 14.8 to 25.4	0.668			38.02
Water (%)	95	90%			1.05

*The physic chemical characterization of human urine used here are from [39]

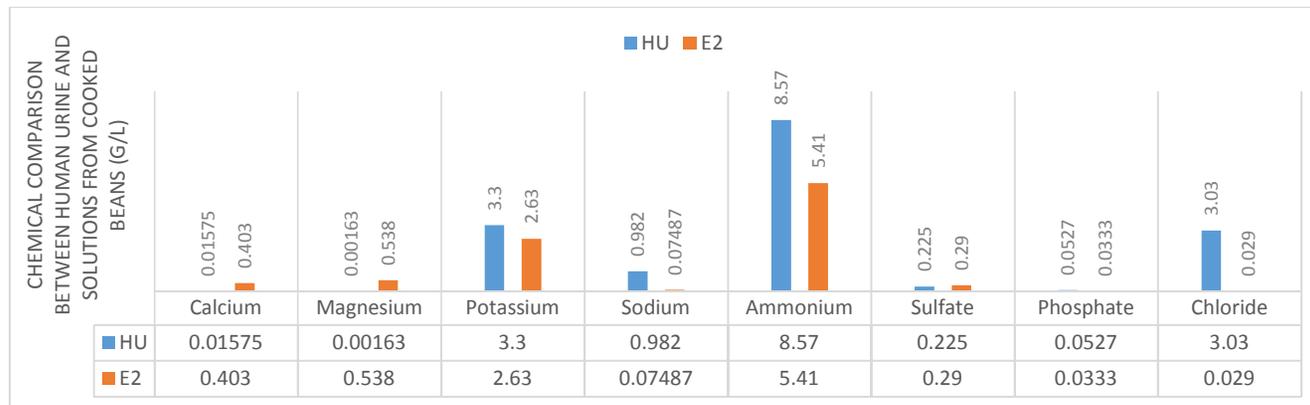


Fig. 5. Chemical composition of human urine and solutions from cooked beans

The phosphate content varies between 0.05022 and 0.0527 g / l [39] in human urine. In the bean end-of-cooking solutions, it is 0.0333g / l (Table 2). It represents 0.4% of all major macro elements [71] in the two fluids. As showed in Fig. 5, phosphates are more concentrated in human urine than in the bean end-of-cooking solutions. However, the ratio between the phosphate content in the urine and the content of the same element in the bean end-cooking solutions is 1.18 (Table 2). This shows that the concentration of this element in these two fluids is comparable.

The potassium content varies between 0.5 and 3.3g / l [39] in human urine. In bean end-of-cooking solutions, it is 2.63g / l (Table 2). It represents 28% of all major macro elements [71] in human urine and 33% of major macro elements in the end-of-cooking solutions of beans. As showed in Fig. 5, depending on the subject's conditions, potassium may be more concentrated in human urine than in the bean end-cooking solutions. However, the ratio between the potassium content in the urine and the content of the same element in the bean end-cooking solution is 1.25 (Table 2). This shows that the concentration of this element in these two fluids is just as comparable.

The sulfate content varies between 0.175 and 0.225g / l [39] in human urine. In bean end-of-cooking solutions, it is 0.29 g / l (Table 2). It represents 92.93% of all minor macro elements [71] in human urine and 23.56% of minor macro nutrients in the bean end-cooking solution. As showed in Fig. 5, sulfates are more concentrated in the end of cooking solutions of the bean. The ratio between the sulfate content in the urine and the content of the same element in the bean end-of-cooking solutions of 0.78 (Table 2), confirms this. However, this shows in view of the variable composition of urine that the concentration of this element in these two fluids remains comparable.

The calcium content varies between 0.01334 and 0.01575g / l [39] in human urine. In bean end-of-cooking solutions, it is 0.403g / l (Table 2). It represents 6.5% of all minor macro elements [71] in human urine and 32.73% of minor macro elements in the bean end cooking solutions. As showed in Fig. 5, calcium is far more concentrated in the bean end-cooking solutions than human urine. The ratio between the calcium content in the urine and the content of the same element in the bean end-of-cooking solution is 0.04 (Table 2).

The magnesium content varies between 0.0015 and 0.00163g / l [39] in human urine. In bean end-of-cooking solutions, it is 0.538g / l (Table 2). It represents 0.67% of all minor macro elements [71] in human urine and 43.70% of minor macro elements in the bean end cooking solutions. As showed in Fig. 5, magnesium is far more concentrated in the bean end-of-cooking solution than human urine. The ratio between the magnesium content in the urine and the content of the same element in the bean end-cooking solution is 0.003 (Table 2).

The sodium content varies between 0.938 and 0.982g / l [39] in human urine. In bean end-of-cooking solutions, it is 0.07484g / l (Table 2). As showed in Fig. 5, sodium is much more concentrated in human urine than the bean end-cooking solutions. The ratio between the calcium content in the urine and the content of the same element in the bean end-cooking solutions is 13.12 (Table 2).

The chlorides content varies between 2.24 and 3.03g / l [39] in human urine. In bean end-of-cooking solutions, it is 0.029 g / l (Table 2). As showed in Fig. 5, sodium is much more concentrated in human urine than the bean end-cooking solutions. The ratio between the calcium content in the urine and the content of the same element in the bean end-cooking solution is 104.48 (Table 2).

The electrical conductivity of human urine varies between 14.8 and 0.668mS / cm. That of the bean end-of-cooking solutions is 0.668mS / cm (Table 2). As shown in Fig. 6, it is significantly higher in human urine (HU) than bean end-of-cooking solutions (E2). The ratio between this parameter in the urine and in the bean end-cooking solutions is 38.02 (Table 2).

The pH of human urine (HU) varies between 6.32 and 6.9 according to [39]. That of the bean end-of-cooking solutions (E2) is 6.31 (Table 2). As showed in Fig. 7, this parameter is comparable in the two solutions. The ratio between this parameter in the urine and in the bean end-of-cooking solutions is 1.09 (Table 2).

According to [39], water makes up 95% of human urine (HU). Concerning the bean end-of-cooking solutions (E2), it represents 90%. Its quantity in human urine and in the bean end-of-cooking solutions is comparable (Table 2). In fact, the ratio between this parameter in the urine and in the end-of-cooking bean solution is 1.05.

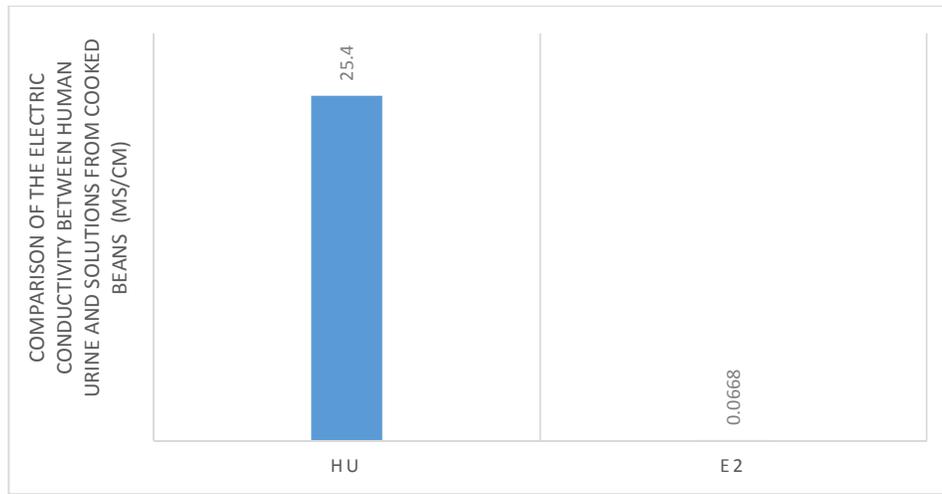


Fig. 6. Electric conductivity of human urine and solutions from cooked beans

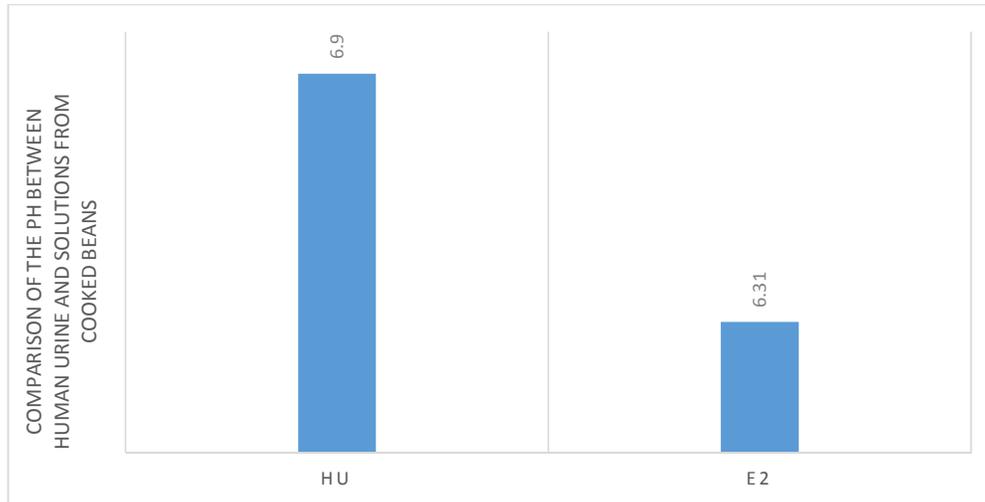


Fig. 7. pH of the human urine and solutions from cooked beans

Generally speaking, human urine and bean-to-bean end-cooking solutions are two fluids that are very similar in composition. Thus, as shown in Fig. 8 below, these are two fluids whose composition is largely dominated by nitrogen and potassium respectively. But, with regard to their respective origin, they will logically present particularities. Thus, human urine is richer in sodium and chlorides, with high electrical conductivity. The bean end-of-cooking solutions for their own are richer in magnesium and calcium. [51] recommends a dilution of human urine in the proportions 1: 4 (urine: water) before application in view of its too high concentration of sodium and chlorides, and, further, because of its high electrical conductivity. Regarding the bean end-of-cooking solutions, its extreme poverty in

sodium and chlorides, crowned with almost zero electrical conductivity does not require dilution before application. But, according to the observations of [14], its application requires hilling to prevent losses of nitrogen and sulfur, particularly in gaseous form. The strong parallelism that exists between their chemical compositions makes these two fluids excellent liquid organic fertilizers.

It would be further important that the bean end-of-cooking solutions be reconsidered from a dietetic point of view with regard to its high nutritional potential. Indeed, in view of its approved chemical composition, this solution could be consumed as a soup in order to recycle the cohort of nutrients it contains.

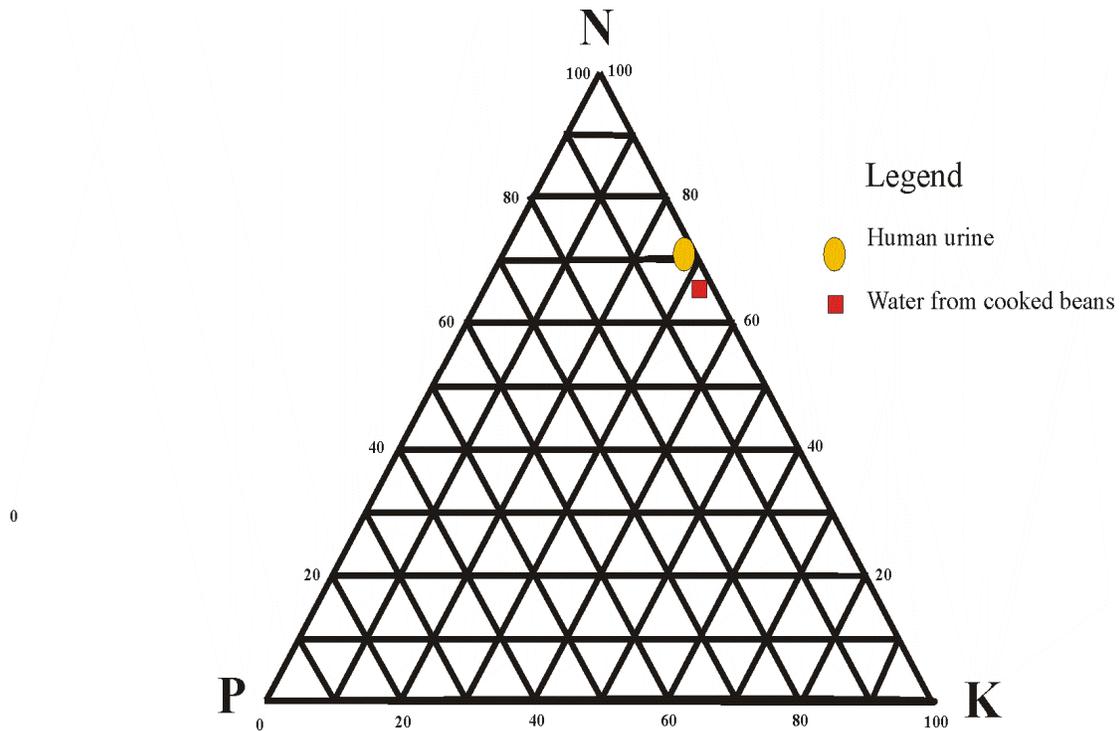


Fig. 8. Position of the human urine and solutions from cooked beans in the N-P-K diagram of [99]

4. CONCLUSION

Solutions from cooked beans are rich in mineral salts, particularly major macro elements (N and K) and minor macro elements (Ca, S, Mg). Concerning the third major macro element, notably the phosphorous, it is present in low amounts. The advantage of this fluid consists in its low amounts of sodium and chlorides, this coupled to its low electric conductivity. This fluid has a pH of 6.31. It is made of about 90% of water. A deep parallelism can be drawn between the human urine and solutions from cooked beans. In fact, these two fluids are rich in nitrogen and potassium, and mainly made of water. But, in the detail, some particularities are present. Human urine has high amounts of sodium and chlorides, this joined with a high electric conductivity. Concerning solutions from cooked beans, it has high amounts of calcium and magnesium, and a quite nil electric conductivity. The use of solutions from cooked beans does not require a dilution, but a earthing up directly after its application in other to avoid the loose of sulfur and nitrogen through gas emanation. Moreover, the numerous nutrients contained in solutions from cooked beans can be gainfully recycled as soup after flavoring.

5. RECOMMANDATION

The use of solutions from cooked beans as fertilizers must be directly followed by earthing up in other to avoid the loose of nitrogen and sulfur through gas emanation. It use does not require any dilution.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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